MINERAL CHANGES IN SUCCESSIVE VOLCANIC FLOWS

Senior Thesis

Presented in Partial Fulfillment of the
Requirements for Bachelor of Science by

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ABSTRACT

Samples of ten successive volcanic flows were collected from the Marysvale area, Utah. A traverse was made on Agate Peak. The samples were analyzed by standard petrographic techniques to determine mineralogic changes. Results of this study indicate that successive flows at increasing depths originated from an earlier-differentiated magma chamber.

INTRODUCTION

The purpose of this thesis is to examine a series of volcanic flows and determine mineral changes. This was done to determine how the composition of a magma chamber changed with age. The expected results were that the plagioclase in the sample would become increasingly sodic with age. Additionally, it was expected that the quartz and potassium-feldspar content would increase with age. Collecting of the samples was done in August, 1980 in the Marysvale Volcanic Field. This area is 23 miles south of Richfield, Utah. Samples were collected from ten conformable flows. Thin sections were cut and analyzed to determine how the composition of the flows (and therefore the magma chamber) changed with age. The results of this study are not necessarily applicable to other flows and generalizations can only be stated for this series. The conclusions of this thesis were based on the following criteria: the composition of feldspars and pyroxenes, the other minerals present, the relative percent of phenocrysts to groundmass.

METHOD

Collecting of samples was done on an exposed slope in the Marysvale Volcanic Field (Figure 1A/B/C). Weathered mater-

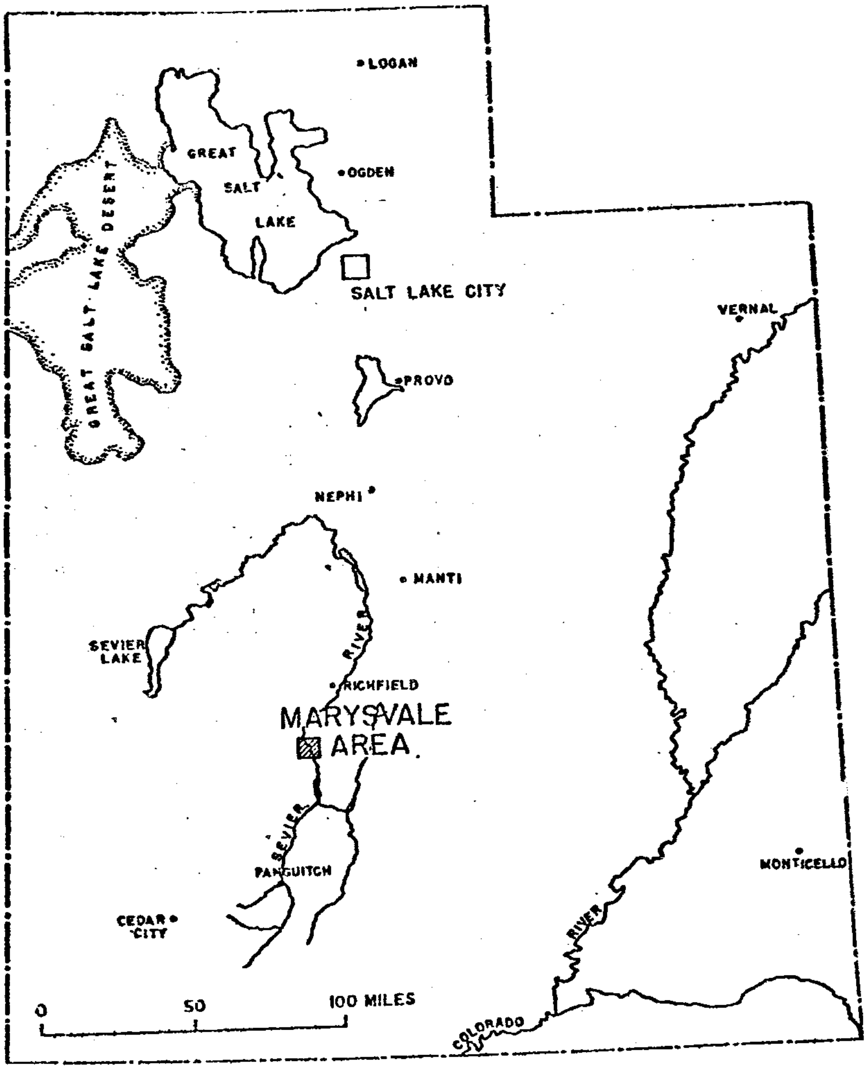
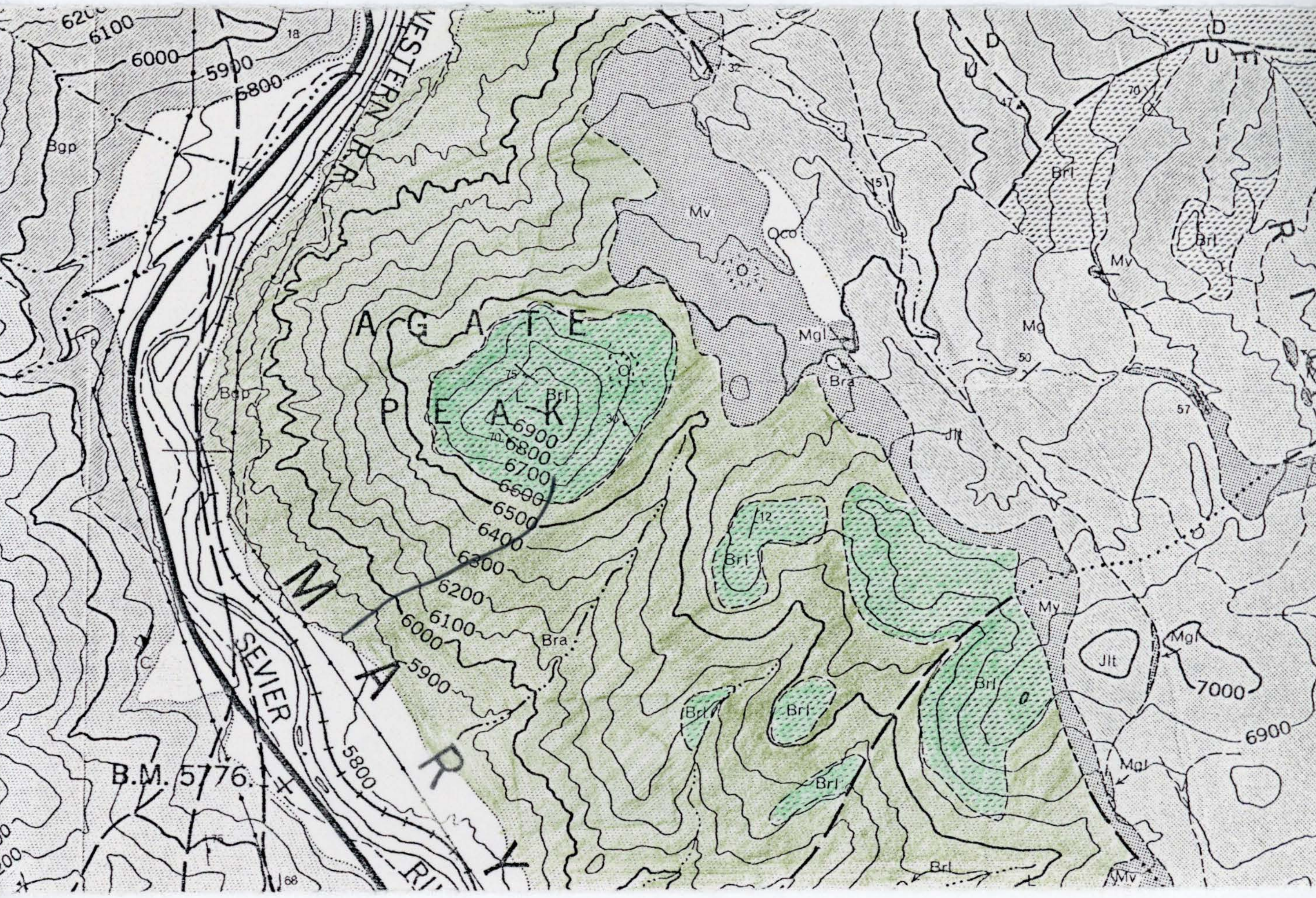
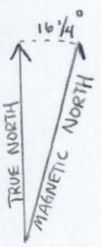
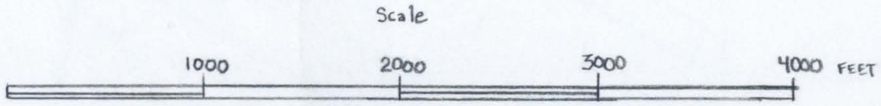


Figure 1A. General sampling area. Adapted from Kerr, 1957.







Contour Interval 100 feet

Figure 1B. Traverse path in solid line on Agate Peak. Adapted from Kerr, 1957. Brl and Bra are both members of the Bullion Canyon volcanic series. Brl is the Rock Candy latite, Bra is the Rock Candy agglomerate. Age of both is early Tertiary.

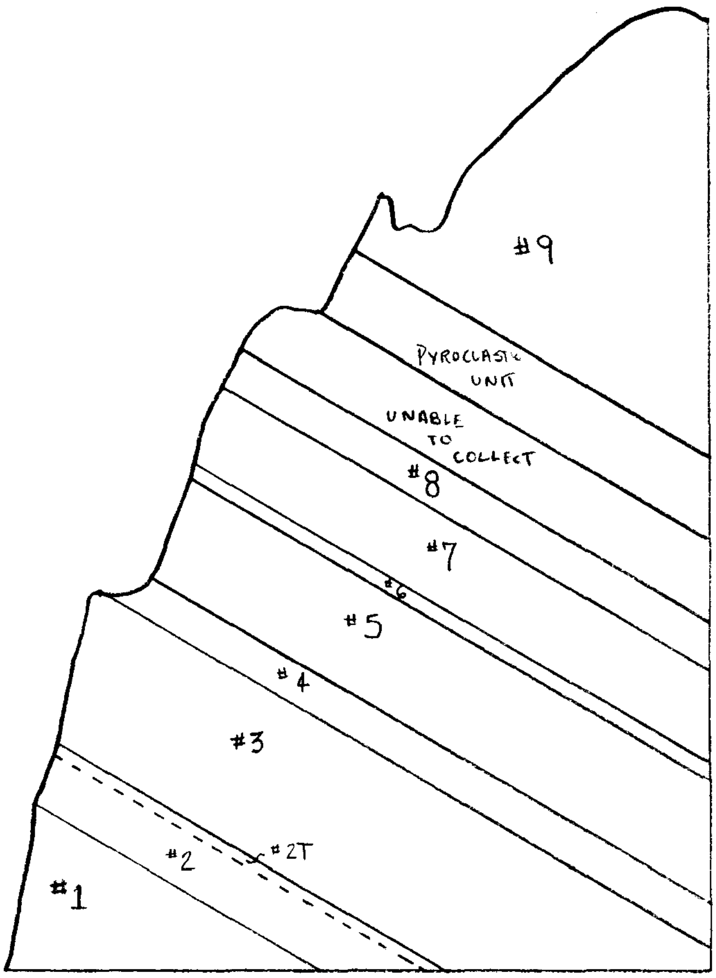


Figure 1C. Schematic sketch of sample collecting area. Units given in relative thickness only. Vertical interval shown is about 1000 feet.

ial and fresh samples were collected from each of the ten units studied. The fresh rock was collected from a minimum of six inches below the weathered surface of the outcrop using sledgehammers and pry bars. A total of sixteen thin sections were studied (approximately two from each rock type) using standard petrographic techniques.

DATA

Data for this thesis is presented as thin section descriptions. The top unit collected, unit nine, is the first unit covered. Information gathered on lower units is less dependable due to alteration of phenocrysts.

Level 9, PC-6

This rock is a basalt containing phenocrysts of plagioclase, pyroxene and amphibole. The groundmass is mainly feldspar (mostly sodic plagioclase) and opaques. Plagioclase phenocrysts are euhedral and exhibit albite twinning. They range in size from .25 to nearly 3 mm. The clinopyroxene, augite, is present in octagonal grains .2 to .3 mm in size and show simple twinning. Subhedral biotite, as an alteration product of ferromagnesium minerals, is present as brown pleochroic grains from .25 to .4 mm in size. A single .5 mm amphibole, probably hornblende, is present. The opaques in this rock are magnetite, ranging in size from .25 to .35 mm.

Groundmass: 75% Phenocrysts: 25%

Phenocrysts

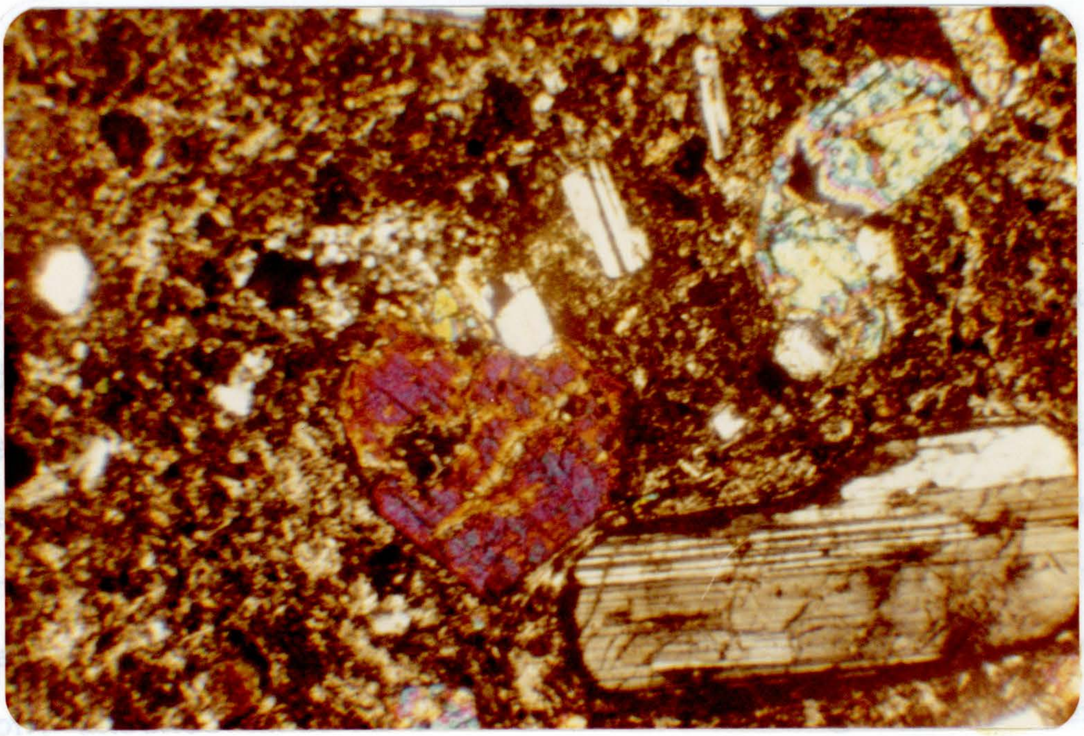
Plagioclase: 75-80%	Biotite, Amphibole: Trace
Augite: 10-15%	Accessories: Apatite
Opaques: 5-10%	Alteration Products: Chlorite, Carbonate, Hematite

Determination of plagioclase composition by the Michel-Levy method. Angles obtained: 26°, 28°, 32°, 30°.

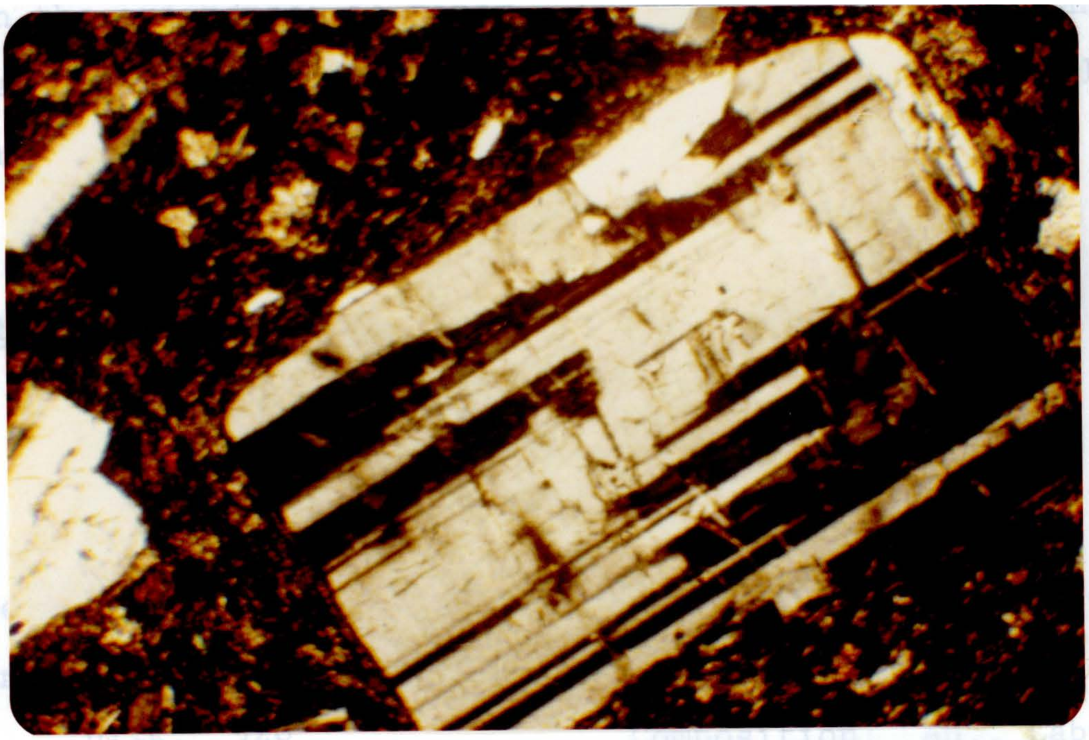
High: 32° Composition: An_{58} Labradorite

Pyroxene 2V's: Range from 55°-60°

Composition: Augite



Photograph 1: Level nine. Shows the typical euhedral pyroxenes and plagioclase in this unit. (56X, crossed nicols)



Photograph 2: Level nine. Typical plagioclase showing albite twinning. (56X, crossed nicols)

Level 8, PC-5d

This basalt contains phenocrysts of feldspars and carbonate pseudomorphs. Both are present in a groundmass of hematite and feldspar. The feldspar phenocrysts are euhedral plagioclase that range in size from .1 to .5 mm. The majority are about .2 to .3 mm in size. Albite twinning predominates but some are untwinned. Carbonate pseudomorphs range in size from .3 to .5 mm. Opaque rims of hematite are present around nearly all of these pseudomorphs. In addition, another unknown brownish-red ferromagnesium alteration product is present as subhedral to anhedral grains. The plagioclase is slightly altered to carbonate. This is especially prevalent in the somewhat zoned cores. Alteration in the groundmass is minor. Chlorite is present as an alteration of ferromagnesium minerals. Carbonate infillings are also present.

Groundmass: 50-55% Phenocrysts: 45-50%

<u>Phenocrysts</u>

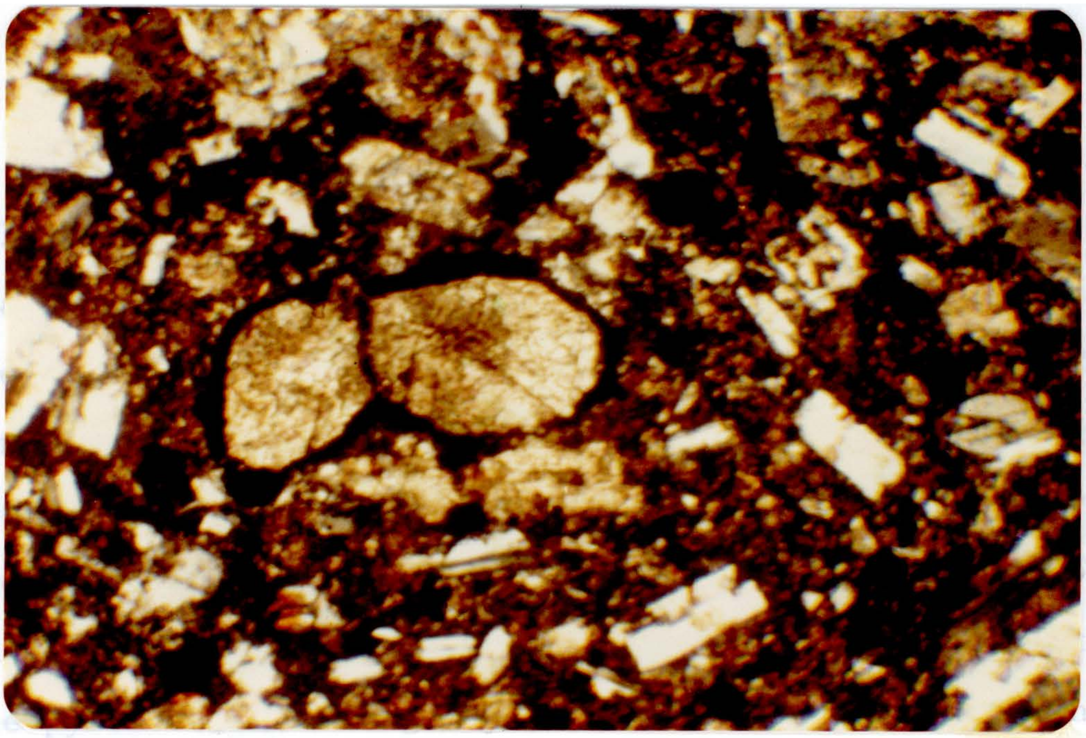
Plagioclase: 85-90%
Carbonate Pseudomorphs: <5%
Opaques: 5-10%

Determination of plagioclase by the Michel-Levy method.

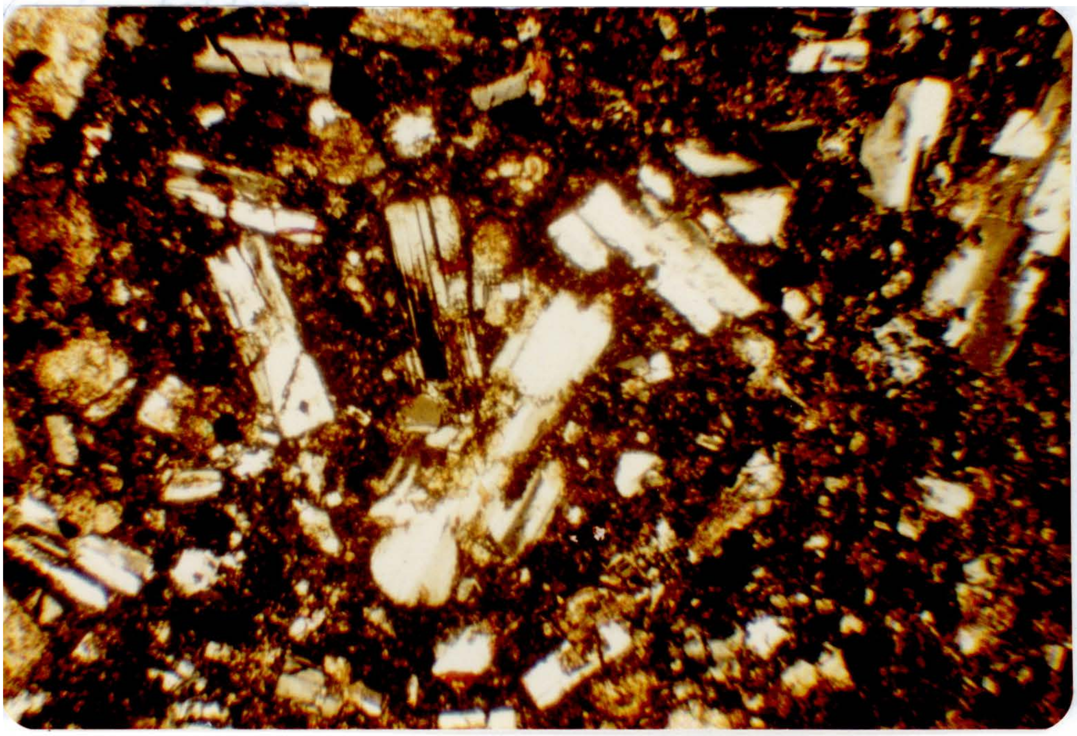
Angles obtained: 30°, 33°, 34°, 31°, 33°, 25°, 30°.

High: 34° Composition: An_{60} Labradorite

Pyroxene 2V's: Indeterminate, due to alteration.



Photograph 3: Level eight. Shows typical carbonate pseudomorph after pyroxene. (56X, crossed nicols)



Photograph 4: Level eight. Shows feldspar with alteration. (56X, crossed nicols)

Level 7, PC-5c

This rock is a basalt that contains phenocrysts of feldspar and pyroxene in a predominantly feldspar and opaque groundmass. Feldspar phenocrysts are euhedral and show some alteration to sericite and clay minerals. They range in size from .25 to .5 mm and exhibit albite twinning. Untwinned plagioclase usually shows normal zoning. Pyroxene phenocrysts show simple twinning and are .5 to .75 mm in size. Pigeonite and augite are both present. Most of the pyroxense are slightly altered to carbonate. Amphiboles have been totally replaced by carbonate and have opaque rims of hematite. A green fibrous ferromagnesium alteration product (serpentine?) is present. The groundmass contains feldspar of both potassium feldspar and plagioclase and opaques.

Groundmass: 60-70% Phenocrysts: 30-40%

Phenocrysts

Plagioclase: 65-75%
Clinopyroxene: 5-10%
Carbonate Pseudomorphs: <1%
Chlorite-Serpentine Alteration: 5%
Opaques: 10-15%

Accessories: Apatite

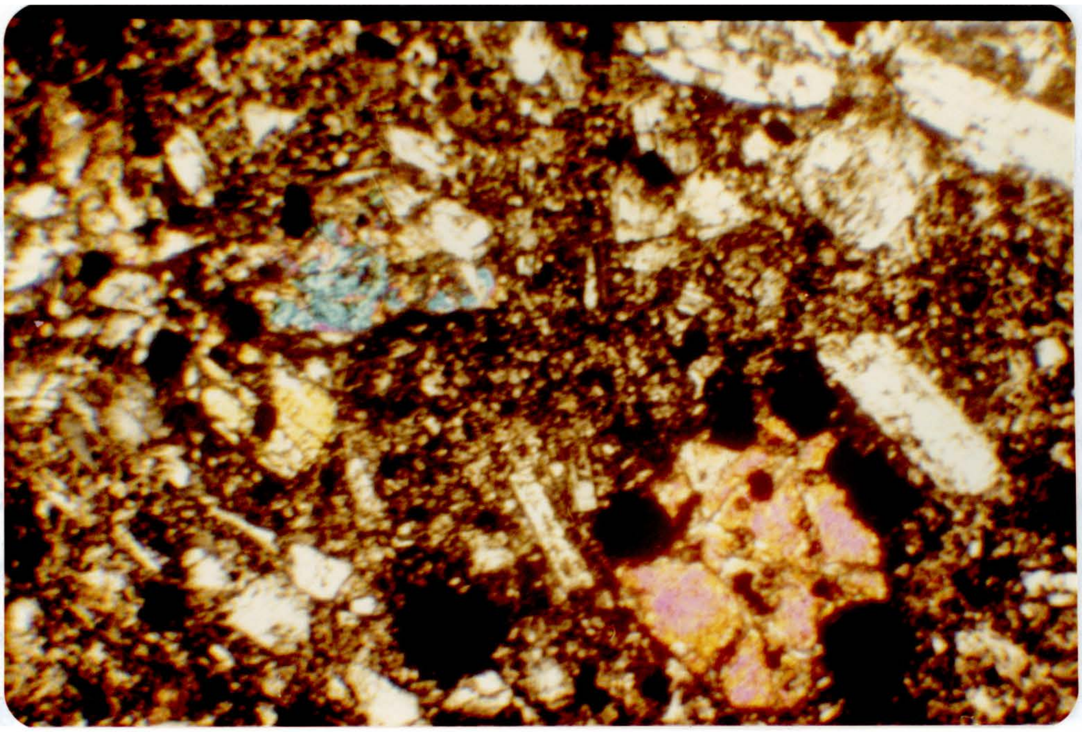
Alteration Products: Sericite, Chlorite, Serpentine, Hematite, Carbonate

Determination of Plagioclase by the Michel-Levy method.

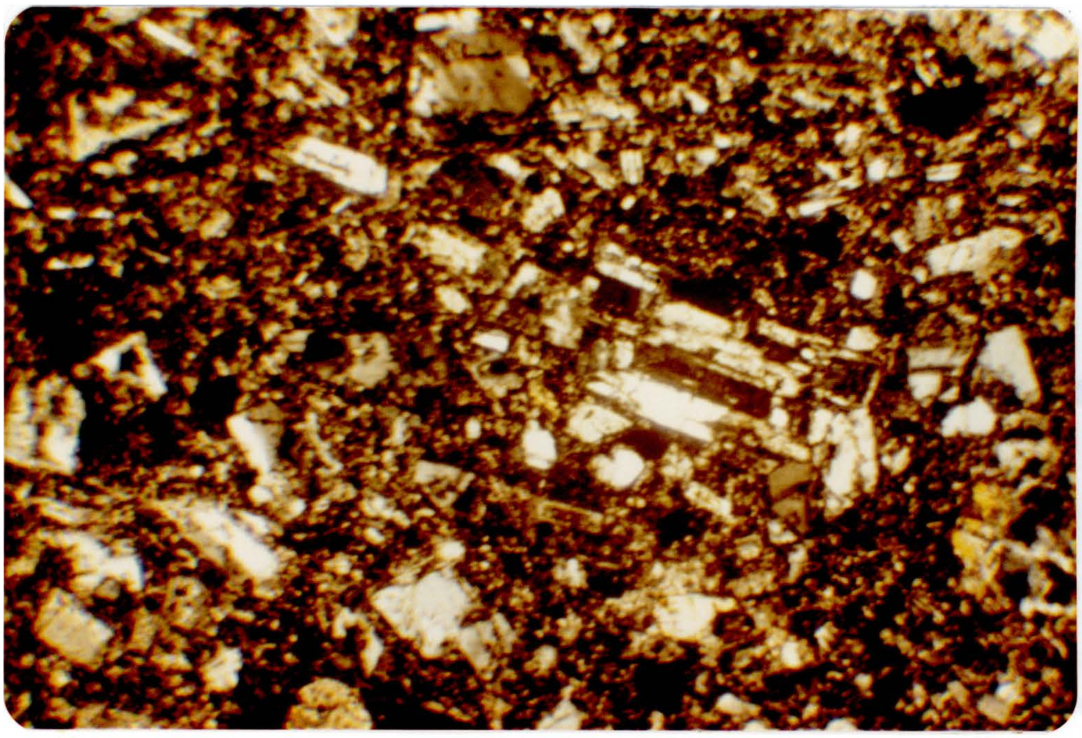
Angles obtained: 26°, 29°, 30°, 31°.

High: 31° Composition: An_{55} Labradorite

Pyroxene 2V's: 40° Pigeonite; 55° Augite



Photograph 5: Level seven. Clinopyroxene is blue, orthopyroxene is red. (56X, crossed nicols)



Photograph 6: Level seven. Typical plagioclase showing alteration to carbonate. (56X, crossed nicols)

Level 6, PC-5b

This is an altered pyroxene andesite containing feldspar and carbonate pseudomorphs (after pyroxene) as the phenocrysts. Phenocrysts are present in a feldspar-rich groundmass that contains magnetite and both potassium feldspar and plagioclase. The plagioclase phenocrysts range in size from .25 to .75 mm. Most are altered to clay minerals and sericite. The potassium feldspar phenocrysts are quite small (about .1 mm in size). Nearly all of the pyroxene, augite, has altered to carbonate. Pyroxenes average about .25 mm in size. Some carbonate pseudomorphs after amphibole may also be present. Minor chlorite is present as alteration of ferromagnesium minerals.

Groundmass: 65-70% Phenocrysts: 30-35%

Phenocrysts

Plagioclase: 50-60% Opaques: 10-15%
K-feldspar: 5-10% Chlorite: 1-3%
Pseudomorphs of Pyroxene and Amphibole: 10-15%

Alteration Products: Sericite, Hematite, Carbonate, Serpentine, Kaolin

Accessories: Apatite

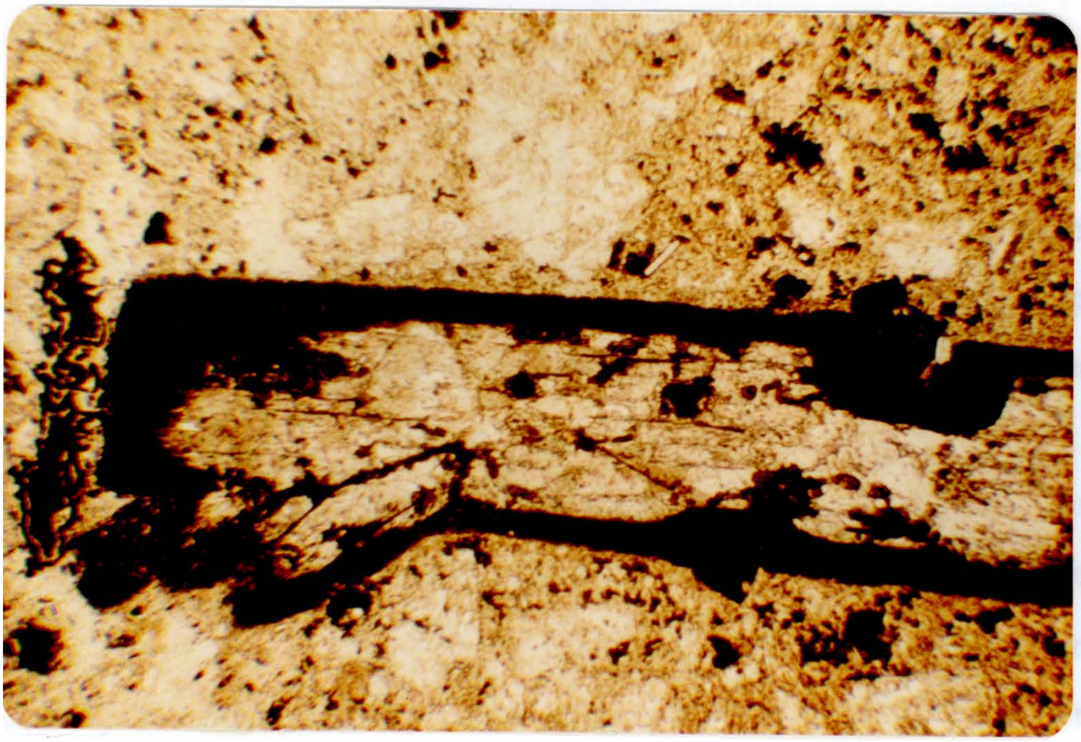
Plagioclase composition by the Michel-Levy method.

Angles obtained: 22°, 20°, 21°.

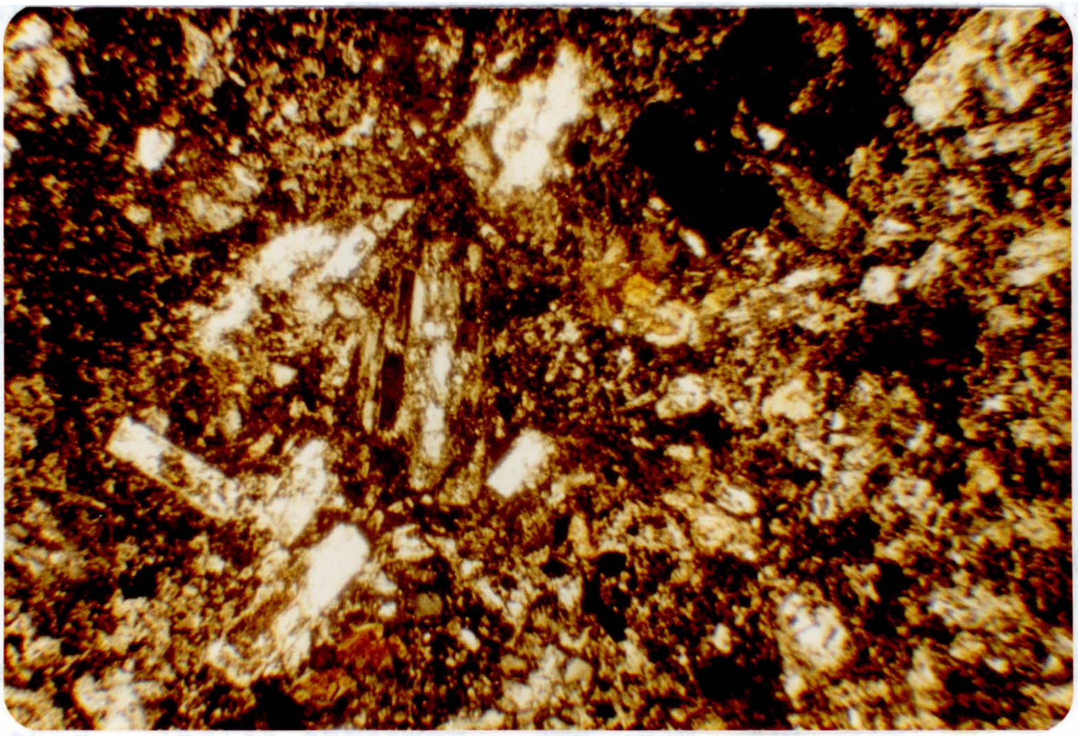
High: 22° Composition: An_{41} Andesine

Pyroxene 2V's: 55°-60°

Composition: Augite



Photograph 7: Level six. Carbonate pseudomorph after amphibole with hematite rim. (56X, crossed nicols)



Photograph 8: Level six. Typical plagioclase showing alteration to clay minerals. (56X, crossed nicols)

Level 5, PC-5A

This is an altered basalt that contains phenocrysts of feldspar, chlorite, clinopyroxene and carbonate psuedomorphs. Phenocrysts are present in a groundmass of feldspar, opaques, and quartz. The quartz is subhedral to euhedral. This is the first unit below the top of the exposure (Level 9) that has observable quartz. The feldspar phenocrysts are euhedral plagioclase partially altered to clay minerals, sericite, and carbonate. Sizes range from .25 to 1 mm and many grains are over 50% altered. Most of these pseudomorphs are about .5 mm in size. Chlorite is present in subhedral flakes up to .3 mm. It occurs as an alteration product of amphibole in some cases and is primary in others. Carbonate is present as fracture infilling. Magnetite phenocrysts are peripherally altered to hematite. Trace amounts of pleochroic brown biotite are present.

Groundmass: 55-65% Phenocrysts: 25-35%
Carbonate Infilling: 5%

<u>Phenocrysts</u>

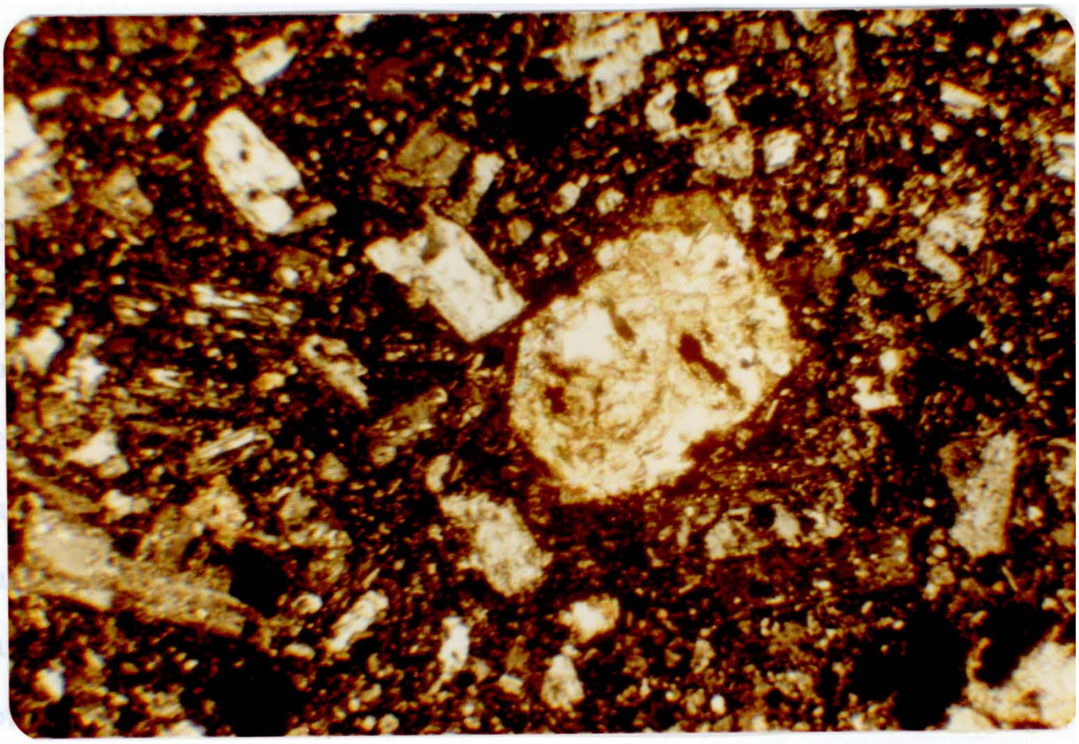
Plagioclase: 70-80% Clinopyroxene: 1-3%
Chlorite, Biotite: <5% Opaques: 5-10%
Amphibole: 5%

Alteration Products: Hematite, Carbonate, Chlorite, Clay minerals

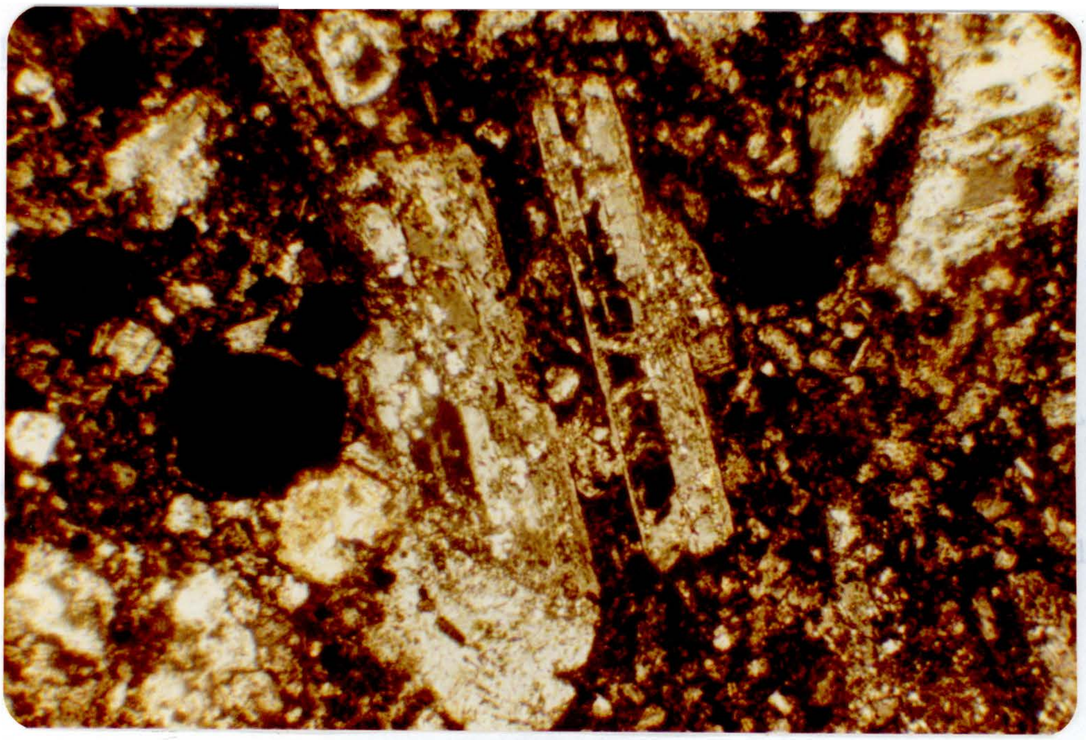
Determination of plagioclase composition by the Michel-Levy method. Angles obtained: 30°, 27°, 32°, 31°.

High: 32° Composition: An_{58} Labradorite

Pyroxene 2V's: 40°; Pigeonite



Photograph 9: Level five. Typical clinopyroxene altering to carbonate. (56X, crossed nicols)



Photograph 10: Level five. Typical plagioclase altering to sericite and carbonate. (156 X, crossed nicols)

Level 4, PC-4

This is an andesine porphyry containing feldspar phenocrysts in a feldspar and opaque groundmass. The groundmass contains feldspar of both potassium feldspar and plagioclase composition. Opaques in the groundmass are magnetite and hematite. The phenocrysts in this rock are plagioclase that have been altered to carbonate and sericite. Normal zoning and/or albite twinning are present on most grains. Grains range in size from .2 to .9 mm. Most are euhedral. Carbonate pseudomorphs after pyroxene are present. Chlorite seems to have replaced amphibole. Carbonate occurs as fracture infilling.

Groundmass: 40-50% Phenocrysts: 30-40%
Carbonate Infilling: 10%

<u>Phenocrysts</u>

Plagioclase: 75-80%	Chlorite: 5%
Carbonate Pseudomorphs: 5%	Opaques: 10-15%

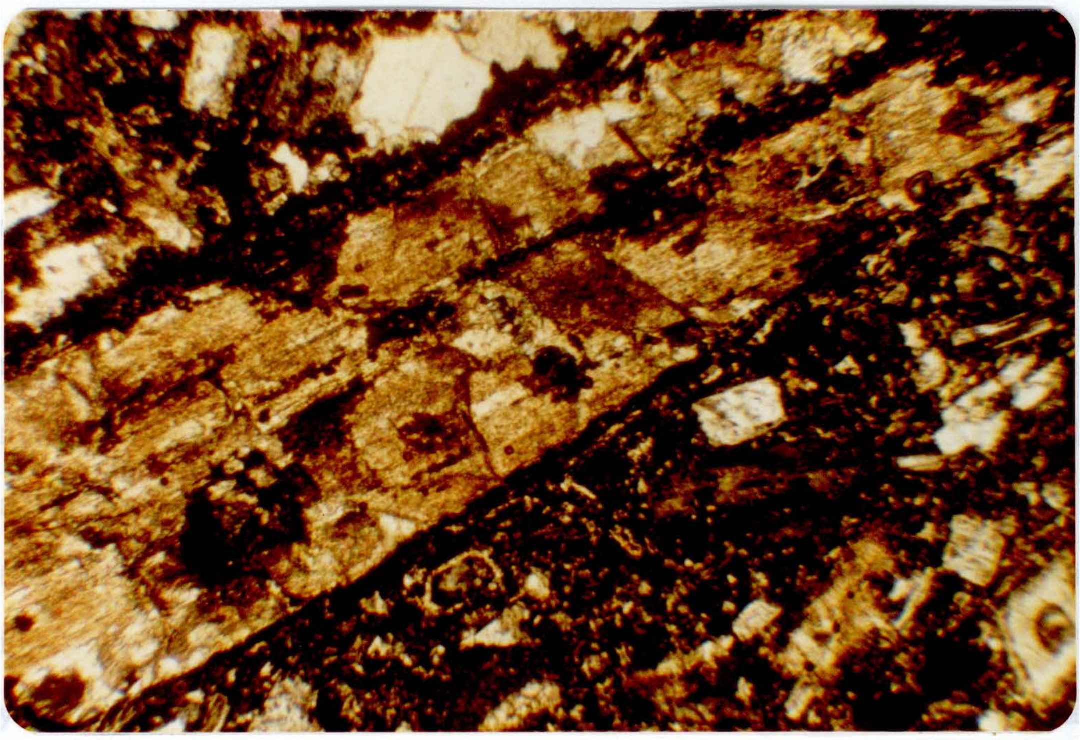
Alteration Products: Chlorite, Carbonate, Hematite, Kaolin

Accessories: Apatite

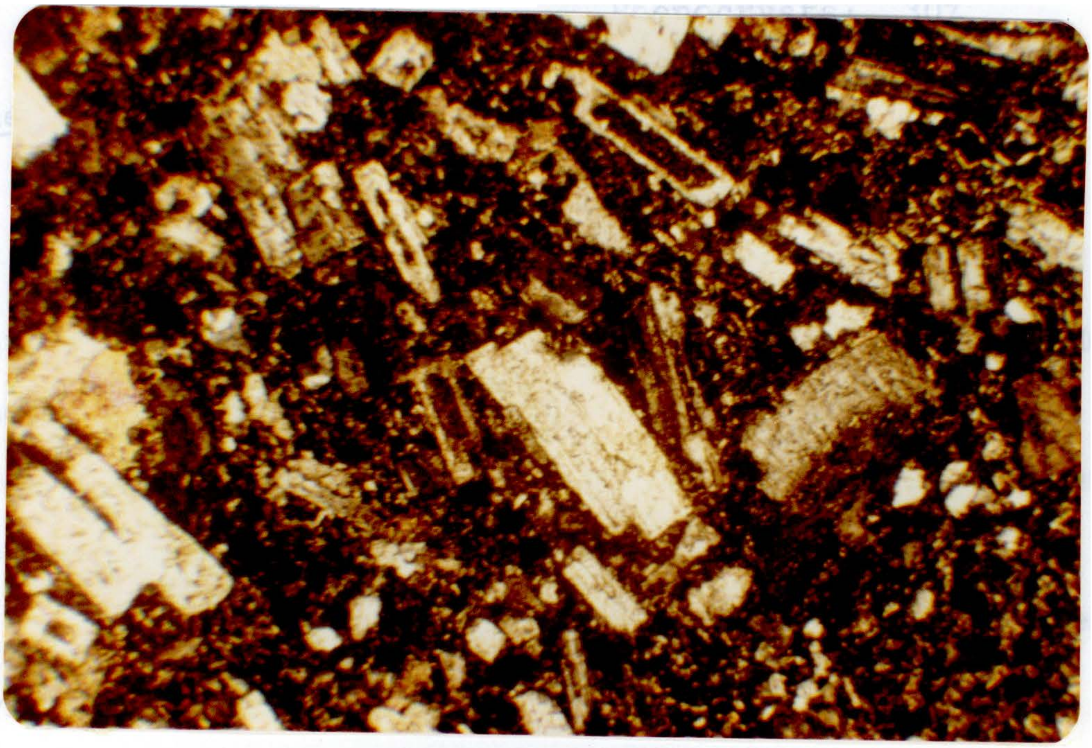
Plagioclase composition as determined by the Michel-Levy method. Angles obtained: 16°, 18°.

High: 18° Composition: An_{36} Andesine

Pyroxene 2V's: None available for determination.



Photograph 11: Level four. Carbonate pseudomorph after pyroxene. (56X, crossed nicols)



Photograph 12: Level four. Plagioclase showing typical zoning, alteration. (56X, crossed nicols)

Level 3, PC-3

As in level four, this rock also appears to be an andesine porphyry. Feldspar phenocryst are present in a feldspar-quartz-opaque groundmass. Euhedral plagioclase exhibiting albite twinning are .2 to .5 mm in size and are partly altered to sericite and/or kaolin. Some euhedral potassium feldspar grains are present up to .2 mm in size. Carbonate occurs as fracture infilling as as replacement of ferromagnesium minerals. Chlorite pseudomorphs after pyroxene are present up to .5 mm in size. Euhedral and anhedral quartz is present in the groundmass. The opaque mineral is magnetite; hematite tims are present around these and the carbonate pseudomorphs.

Groundmass: 60% Phenocrysts: 30%
Carbonate Infilling: 10%

Phenocrysts

Plagioclase: 75-80%	Opaques: 10-15%
Potassium Feldspar: 5-10%	Carbonate Pseudomorphs: Trace

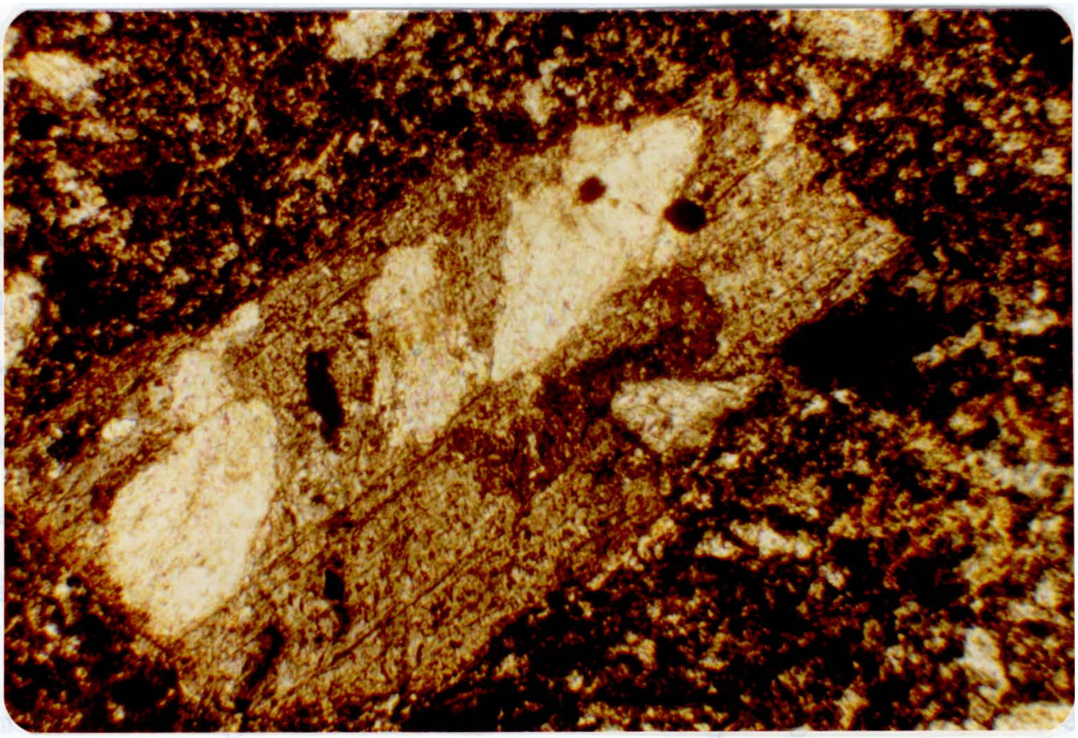
Alteration Products: Sericite, Chlorite, Carbonate, Hematite

Accessories: Apatite

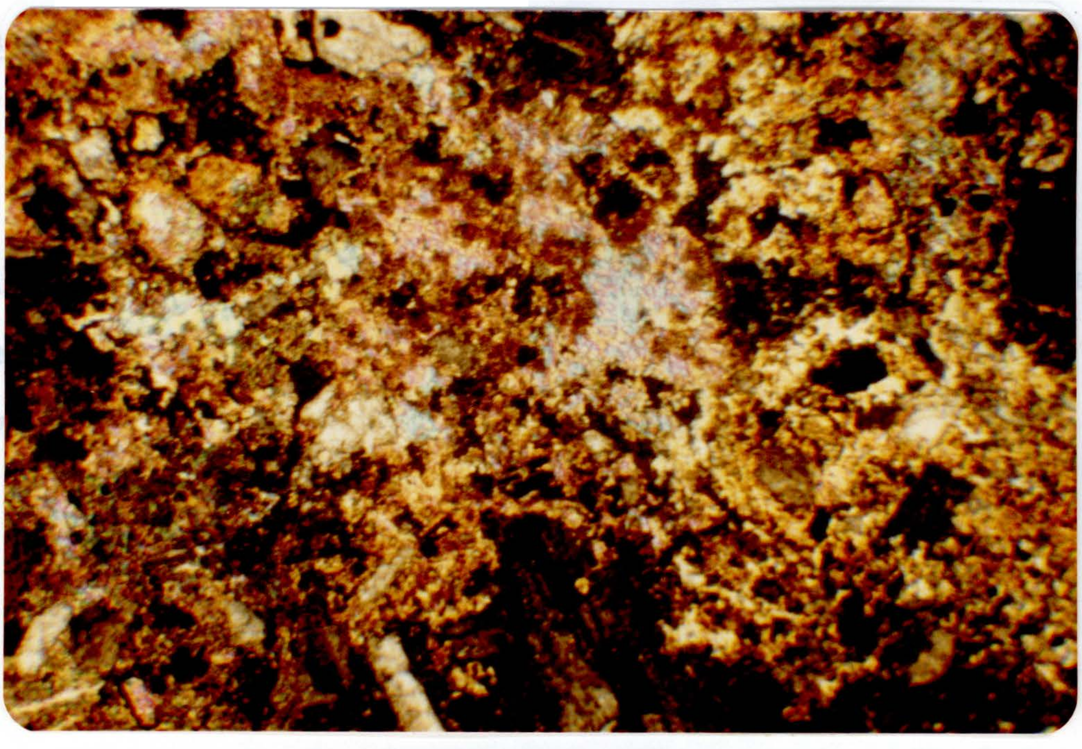
Plagioclase composition as determined by the Michel-Levy method. Angles obtained: 17°, 16°, 15°, 15°.

High: 17° Composition: An_{35} Andesine

Pyroxenes: None available for determination.



Photograph 13: Level three. Carbonate pseudomorph after feldspar. (156X, crossed nicols)



Photograph 14: Level three. Carbonate infilling and plagioclase. (56X, crossed nicols)

Level 2 Top, PC-2T

This rock is a highly altered basalt. Practically all of the phenocrysts are carbonate pseudomorphs after feldspar, amphibole, and pyroxene. Carbonate pseudomorphs after pyroxene were found up to .5 mm in size. Pseudomorphs after amphibole were up to 1 mm in size and the pseudomorphs after feldspar were .2 to .7 mm in size. Magnetite is a phenocryst in this rock, occurring as grains up to .25 mm in size. Chlorite replacement of ferromagnesium minerals gives this section a light green tint when viewed in plain polarized light. The groundmass is composed of untwinned, unaltered feldspar, quartz and hematite.

Groundmass: 70-75%   Phenocrysts: 25-30%

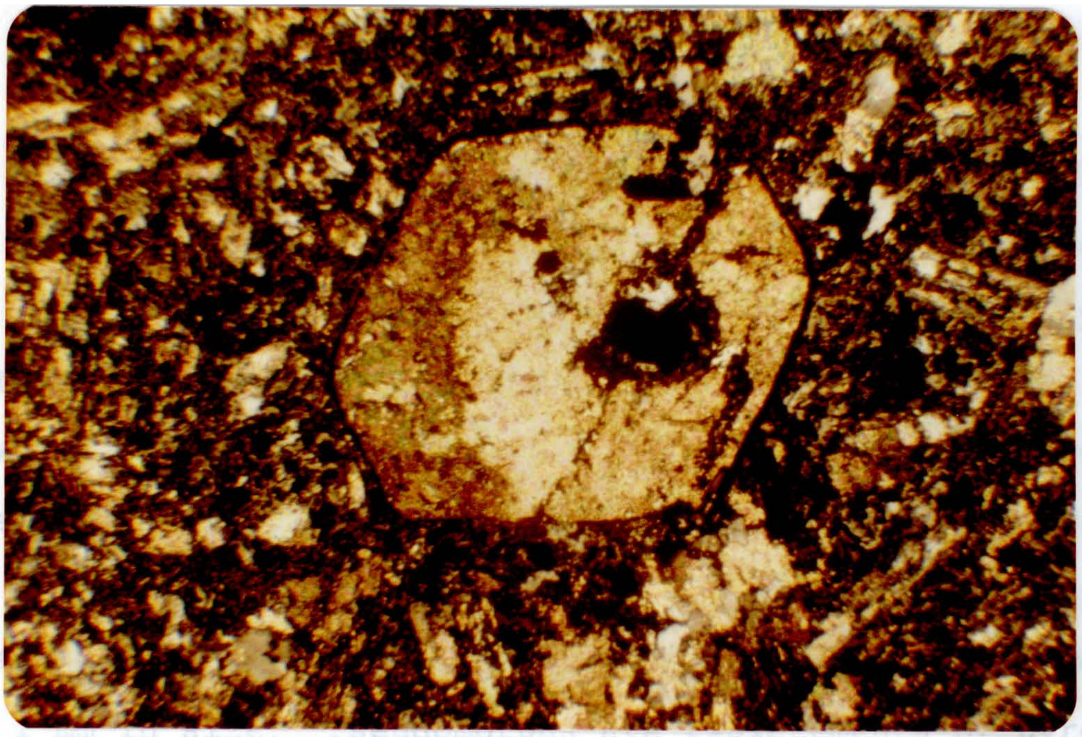
<u>Phenocrysts</u> (all pseudomorphs)

Feldspar: 80-85%
Amphibole and Pyroxene: 5%
Opaques: 10-15%

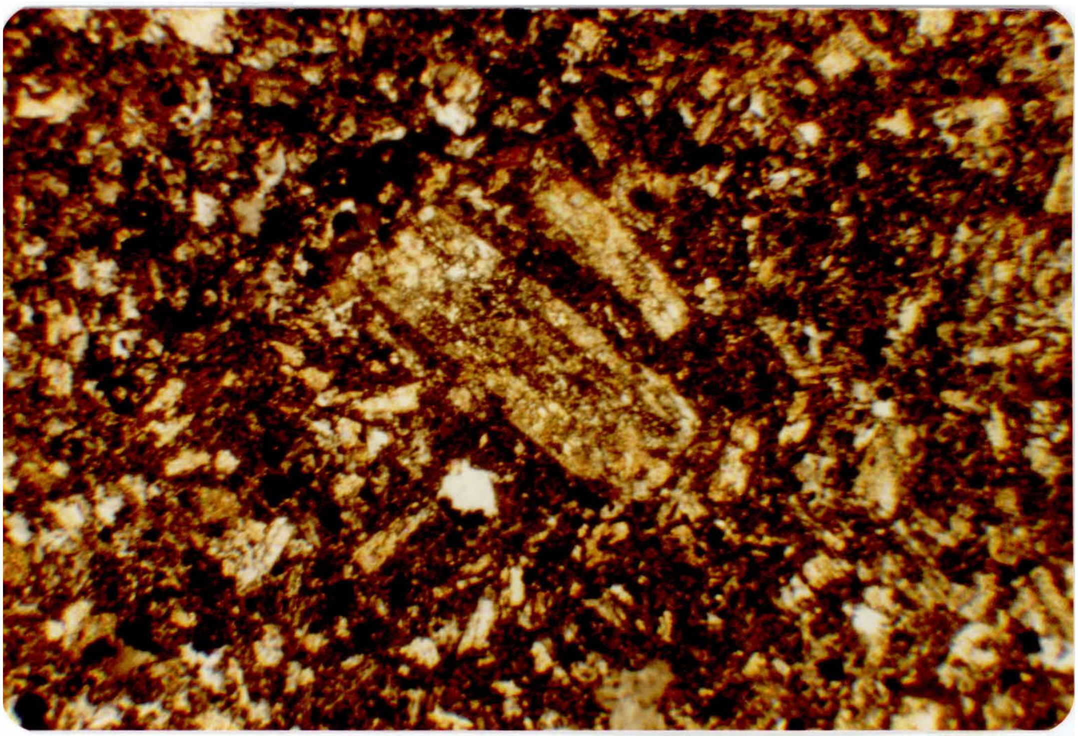
Alteration Products: Sericite, Hematite, Chlorite, Carbonate

Feldspar Composition: Indeterminant

Pyroxene Composition: Indeterminant



Photograph 15: Level 2T. Carbonate pseudomorph after amphibole. (56X, crossed nicols)



Photograph 16: Level 2T. Plagioclase altering to carbonate. (56X, crossed nicols)

Level 2, PC-2

This rock is much less altered than the rock at the top of this layer. This unit is a basalt containing phenocrysts of plagioclase and carbonate pseudomorphs. These are present in a groundmass of potassium feldspar, plagioclase (twinned), carbonate, opaques, and a minor amount of quartz. Plagioclase phenocrysts showing albite twinning are present as euhedral grains from .1 to 1 mm in size. Most are partially altered to sericite. Carbonate pseudomorphs are .5 to 1 mm in size. Pseudomorphs are replacements of pyroxene and amphibole. Chlorite replacement of ferromagnesium minerals is present. Hematite and magnetite are also present.

Groundmass: 60-70%   Phenocrysts: 30-40%

Phenocrysts

Plagioclase: 85-90%
Carbonate Pseudomorphs and Chlorite Replacement: 5%
Opaques: 5-10%

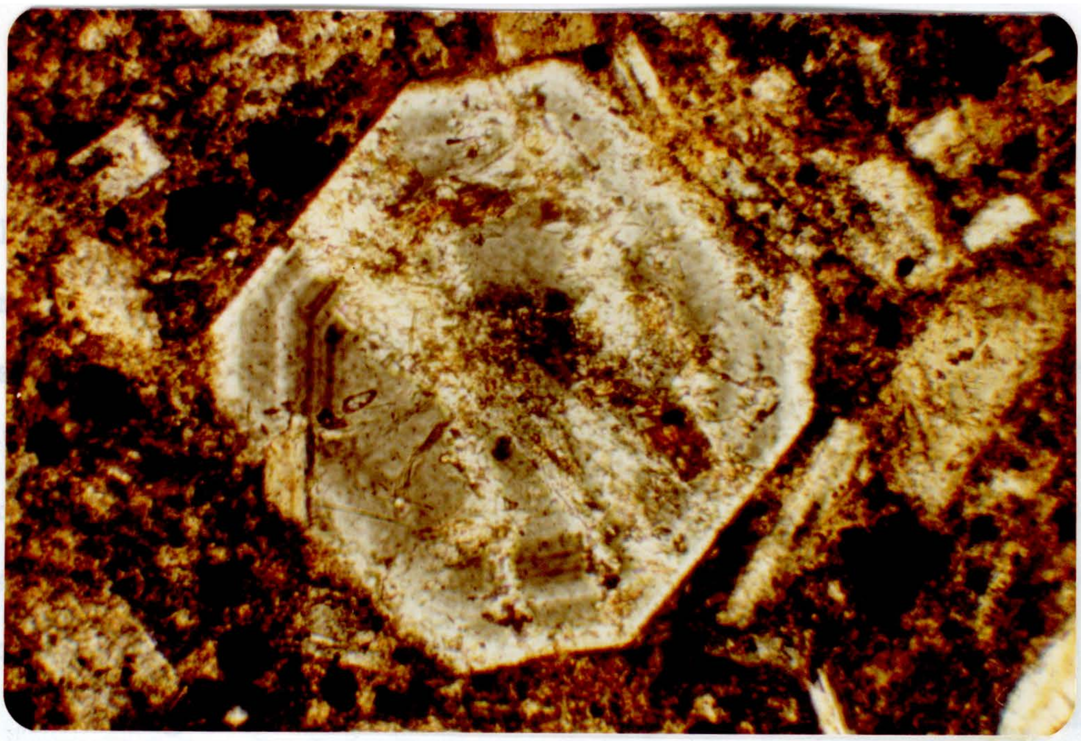
Alteration Products: Chlorite, Carbonate, Sericite, Hematite

Accessories: Apatite

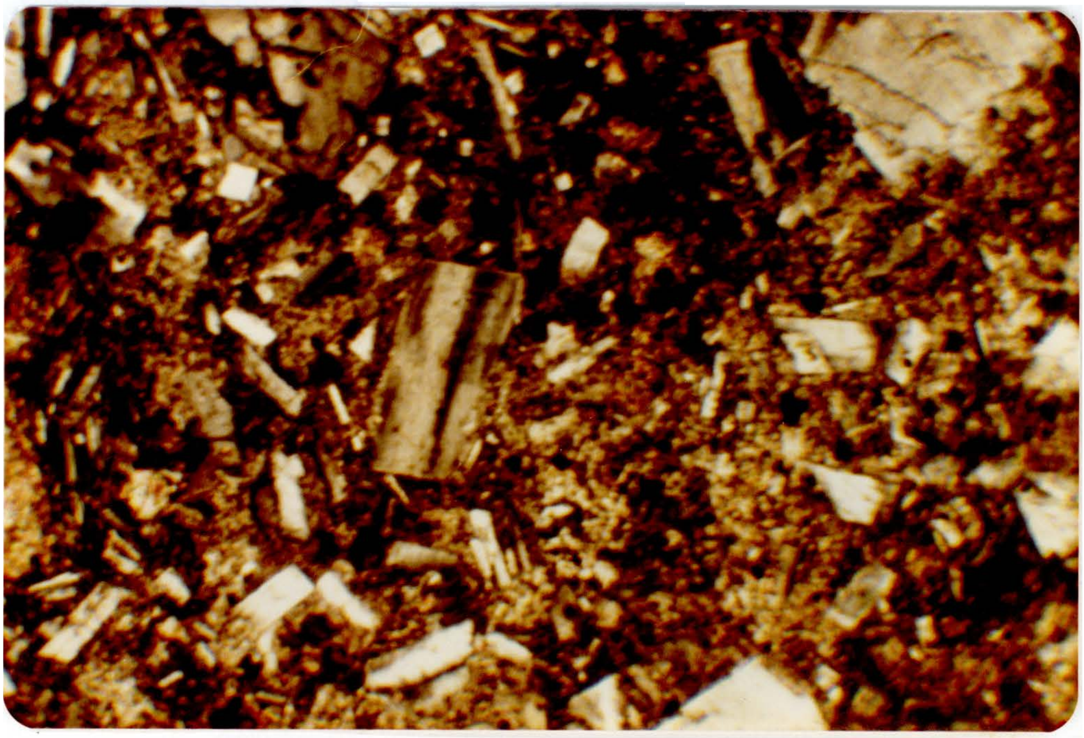
Plagioclase composition as determined by the Michel-Levy method. Angles obtained: 30^{o}, 22^{o}, 26^{o}, 26^{o}.

High: 30^{o} Composition: An_{54} Labradorite

Pyroxenes: Indeterminant



Photograph 17: Level two. Zoned plagioclase altering to carbonate. (156X, crossed nicols)



Photograph 18: Level two. Typical plagioclase, altering to carbonate, sericite. (56X, crossed nicols)

Level 1, PC-1

The alteration in this rock is so extensive that I will call the rock a "basalt" only because of the close correlation of percentages with the rock above it. Phenocrysts of carbonate pseudomorphs after feldspar, pyroxene, and amphibole are present. They are in a groundmass of feldspar, hematite, chlorite, quartz and hematite. Carbonate pseudomorphs after feldspar are .2 to 1 mm in size. Pyroxene and amphibole are .25 to .7 mm in size. Most of the ferromagnesium minerals are replaced by carbonate and have hematite oxidation rims. Some of these pseudomorphs have chlorite cores. The opaque mineral in this rock is hematite, altered from magnetite. The groundmass is unaltered as compared to the phenocrysts.

Groundmass: 60-65% Phenocrysts: 25-30%
Carbonate Infilling: 10%

<u>Phenocrysts</u> (pseudomorphs)

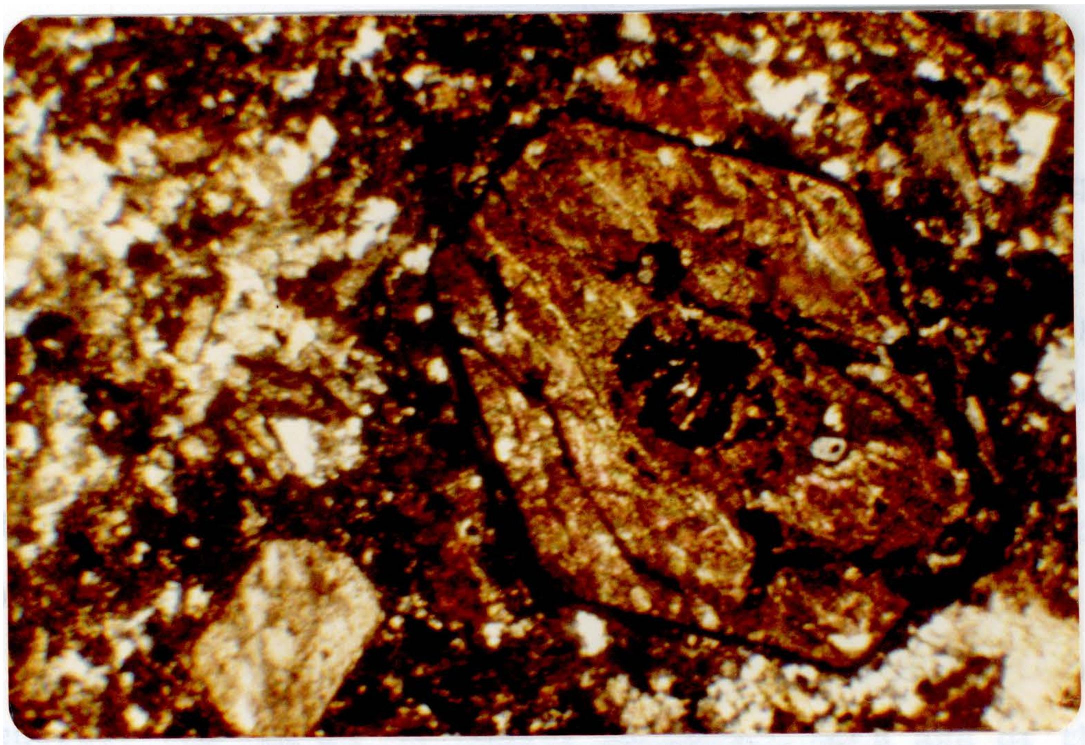
Feldspar: 80-85%
Pyroxene, Amphibole: 5%
Opaques: 5-10%

Accessories: Apatite

Alteration Products: Chlorite, Carbonate, Hematite

Feldspar Composition: Indeterminate

Pyroxene Composition: Indeterminate



Photograph 19: Level one. Carbonate pseudomorph after amphibole. (56X, crossed nicols)

GENERALITIES

No uniform changes occurred in this study. But, if a few anomolies can be temporarily ignored, a few generalities can be made. Figure 2 shows how the anorthite content of plagioclase changed through the flow sequence. With the exception of units two and five, a decreasing anorthite content occurs toward the bottom.

Another composition change that might well be expected to reveal differentiation trends is that of pyroxene composition. Although alteration hindered this initial goal, a generality can be drawn here. As figure three shows, in general, in the sequence moving downward pyroxene composition changed from: 1) augite to 2) augite and pigeonite to 3) pigeonite.

A third interesting feature of this series is that in general, the amount of quartz increases with age of the flow downward. The upper, later sequences showed no quartz in either phenocrysts or in the groundmass. Increasing amounts of quartz are found in the lower levels as euhedral and anhedral grains. A solid chalcedony vein cut across level two, indicating the higher amount of silica available.

Lastly, the amount of potassium feldspar in this sequence increased with age. No potassium feldspar is present above the fifth level. Although the percentage is low, a general increase in potassium feldspar occurred toward the bottom of the series.

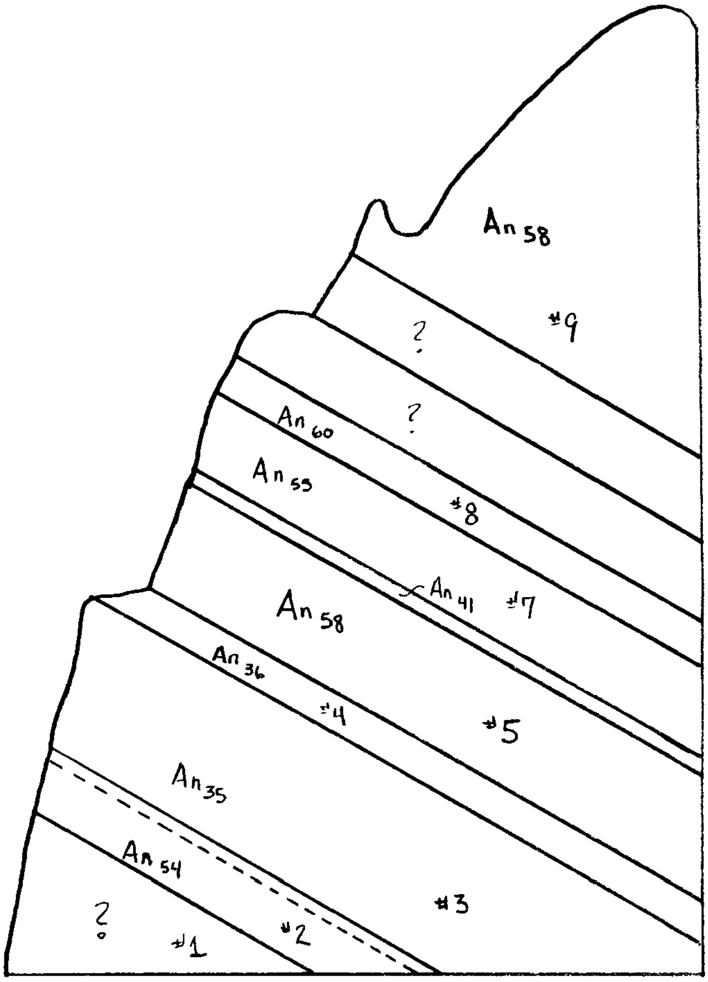


Figure 2. Sketch showing changes in anorthite (An_x) composition. Question marks indicates indeterminant composition.

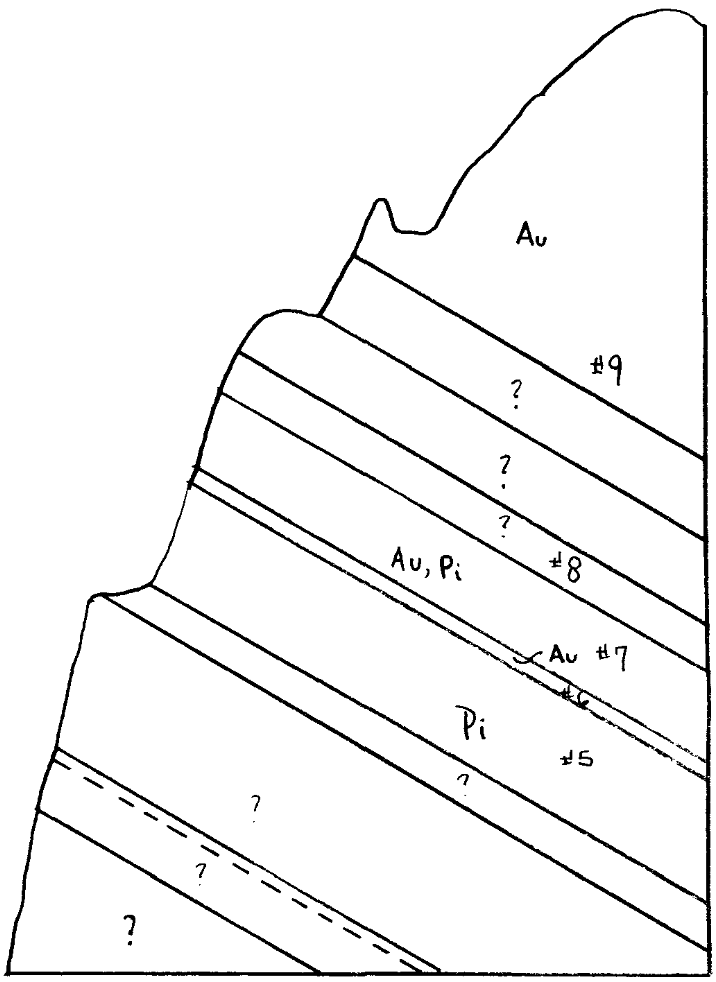


Figure 3. Sketch showing changes in pyroxene composition. Pi = pigeonite, Au = augite, Question mark = indeterminant.

The phenocrysts in the bottom four units (with the exception of 2T) were extensively altered to carbonate. The phenocrysts in the top of the sequence were relatively free of alteration. There was a definite correlation between age of rock and alteration.

DISCUSSION AND INTERPRETATION

In the normal sequence of flows, one would expect the plagioclase to become more sodic with time. This is because the calcic plagioclase crystallizes out of the magma first. As the calcium is used up, the soda-rich feldspars become more prevalent as the magma differentiates. In general, quite the opposite occurred. In addition, quartz would be expected to increase as the magma chamber fractionated. Potassium feldspar would be expected to have become more common with the later flows. None of these relationships seem to have occurred which leads to a different theory of origin.

After reviewing several geologic maps of the area, it was discovered that the collecting of samples was done in two different units of the Mount Belknap Volcanics. Unit nine was collected from the Rock Candy Latite, units one through eight from the Rock Candy Agglomerate. Sources for both flows was to the west and the units had thinned considerably by the time they reached this area. Because of uncertainty that the sources of the Rock Candy Latite and the Rock Candy Agglomerate are the same, I will omit unit nine from further discussion.

It appears that units one through eight went through a reverse sequence of differentiation. This indicates that either the rocks in this area have been overturned, or the chamber had already undergone differentiation before the magma was successively extruded. Data collected from the geologic maps indicating that the beds were not overturned indicates that the latter was the case here.

Although there is obviously no way that I can prove the composition changes occurred due to pre-extrusional differentiation, data collected somewhat supports this theory. The older flows tended to be more sodic and higher in potassium feldspar than the more recent flows. The magma in the chamber had already undergone differentiation before the first flow; the more calcic plagioclase had accumulated on the bottom and the later formed sodic plagioclase had formed at the top. Due to high CO_2 content in the chamber, the sodic plagioclase and ferromagnesium minerals at the top of the chamber underwent deuteric alteration. This alteration is very clearly demonstrated by phenocrysts of carbonate pseudomorphs after feldspar, pyroxene, and amphibole in the lower three layers of the flow. Magma was initially tapped from the upper portion of the chamber. As more magma was extruded, lower layers of more calcic feldspar were tapped and assumed a position overlying the earlier, soda-rich, altered feldspar flows. Since most of the CO_2 had been expelled in earlier flows, deuteric alteration was very minimal in the upper flow units. It is felt the alteration was deuteric, rather than hydrothermal because the groundmass in all of the slides was unaltered as compared to phenocrysts. Also, I do not believe that there was much hydrothermal alteration because of the rarity of zeolites which would be present if hydrothermal alteration was responsible for the carbonate pseudomorphs.

CONCLUSION

Figures two and three summarize the results of this investigation. In general, the composition of this series of flows changed in the following manner. The plagioclase composition went from sodic at the lower earlier flows to calcic later flows at the top. Secondly, in later flows, augite became the more prevalent pyroxene, rather than the pigeonite that was found in the earlier flows. Thirdly, the phenocrysts had been totally altered to carbonate in the lower flows whereas the top flows are much less altered. These changes lead me to believe that this was a series of flows from a magma body with high CO_2 content that had differentiated before the initial extrusion occurred.

SUGGESTIONS FOR FURTHER STUDIES

Allow sufficient time for collecting so that all of the units in the flows can be properly sampled. This probably will take more than a day or two and would involve the use of ropes. Although this would entail extra work, it would be worth the effort to get more data. Also, collecting from other units in the nearby area would be useful. Since the units had thinned greatly by the time they came to rest in the study area, it is possible that some units may not be represented. This is very possible since some of the studied units were only a few feet thick. A final suggestion would be to take pictures of the area.

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